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Research on Safety Signs of Railway Stations Based on Bernoulli Effect and Fluid Dynamics Principles

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Abstract: The purpose of this study is to discuss the necessity and rationality of setting safety signs at train stations through mathematical models, and to analyze the aerodynamic impact of trains passing at full speed on platform personnel. By utilizing the Bernoulli effect and principles of fluid dynamics, combined with factors such as human weight, volume, and distance, a mathematical model is established to quantify the "suction" or "thrust" experienced by platform personnel; At the same time, the basis for setting safety line signs was further explored, and a model was established to describe the relationship between safety distance and factors such as train speed, weight, and volume; Analyze the impact of different factors on the setting of safety signs, and based on existing railway technology management procedures, propose some optimization suggestions to ensure the safety of railway platforms. Firstly, a model I based on the Bernoulli effect was established. Firstly, use the Bernoulli equation to describe the distribution of air velocity and pressure during train passage. Secondly, the thrust received by personnel on the platform at different distances was calculated, and based on the results of Model I, the thrust values under various conditions were obtained through numerical simulation algorithms and MATLAB software, further establishing a safety line setting model. Based on parameters such as train speed, personnel weight, and volume, the basis for setting safety markings was quantitatively analyzed, and the safety distances that should be set at different train speeds were derived.

1. Introduction

On train stations or subway platforms, a yellow or white line is usually drawn about 1 meter from the edge of the platform, which is called a safety line (or safety sign). Passengers must stand outside the safety line while waiting. This design is mainly based on the powerful aerodynamic effects of high-speed trains passing through. According to the Bernoulli effect, when a train passes quickly, it drives the nearby airflow at high speed, causing the air in front of the train to increase speed and pressure, while the air behind the train decreases speed and pressure. This pressure difference generates thrust from the high-pressure area behind the train to the low-pressure area, which may push people towards fast moving trains, causing significant safety hazards [1-2].

To ensure public safety, Article 157 of the Railway Technical Management Regulations stipulates that the distance between the edge of the high platform where passenger trains stop and the centerline of the line is 1750 millimeters, and the distance between the safety line and the edge of the platform is 1000 millimeters. For non high platforms, there are also clear regulations on the distance between safety signs and the edge of the platform, that is, when the train passing speed does not exceed 120km/h, the distance is 1000mm; When the train passes at a speed of 120 km/h to 160 km/h, the distance is 1500 millimeters; When the train passes at a speed of 160 to 200 kilometers per hour, the distance is 2000 millimeters [3].

This article is mainly divided into three parts: (1) Based on the aerodynamic effects generated by trains, considering factors such as train weight, volume, and distance, a mathematical model is established to determine the "suction" or "thrust" of personnel on the platform when high-speed trains or high-speed trains pass at full speed; (2) Based on the results of (1), a mathematical model was established to explain the basis for setting safety line signs on platforms of high-speed trains and power stations; (3) Analyze the impact of different factors (such as train speed, platform design, etc.) on the setting of safety markings, and provide optimization suggestions to the railway department on this basis to ensure the safety of railway platforms [4].

2. Research on the Impact of Aerodynamics on Personnel on Platforms

2.1 Establishment of the model

The paper that needs to be addressed is to quantify the magnitude of the "suction" or "thrust" experienced by people standing on the platform when high-speed trains or bullet trains pass at full speed [5-6]. The task is to establish a mathematical model based on relevant mechanisms, taking into account factors such as weight, volume, and distance between individuals. After removing missing data, we chose to use fluid mechanics and dynamics theory to establish and analyze the model. The specific steps are as follows:

(1) Determine influencing factors: Analyze the main factors that affect "suction" or "thrust", such as train speed, weight and volume of people, distance between people and trains, etc.

(2) Establishing mathematical expressions: Based on the principles of fluid mechanics and dynamics, establish a mathematical model to describe "suction" or "thrust". The model should include the identified influencing factors mentioned above and describe their relationships through mathematical expressions.

(3) Solving the model: using the existing data and numerical calculation methods, solve the model to get the numerical solution of "suction" or "thrust".

(4) Verify the accuracy and reliability of the model: Compare it with actual data or use relevant theories and experiments to verify the accuracy and reliability of the model.

Innovation point: On the basis of solving the paper, attempt to improve the classical fluid mechanics and dynamics models to make the models closer to the actual situation.

Multi model comparison: For the same problem, you can try using two or more different models to solve it, and then compare and evaluate the advantages and disadvantages of different models to draw more accurate and reasonable conclusions.

2.2 Solution of model

In order to establish a specific mathematical model to determine the magnitude of the "suction" or "thrust" of passengers on the platform when high-speed trains or bullet trains pass at full speed, the model is based on the Bernoulli equation and fluid mechanics principles. Here is a simplified model:

Assuming the distance between the people on the platform and the edge of the train is d (in meters), the train speed is v (in meters per second), the weight on the platform is W (in Newton), and the air density is ρ (in kilograms per cubic meter).

The relationship between train speed and air flow rate can be estimated using the Bernoulli equation to estimate the air flow rate v on the platform_ Air (in meters per second). The Bernoulli equation can be expressed as:

$$P_1 + \frac{1}{2}\rho v^2 = P_2 + \frac{1}{2}\rho v_{\text{air}}^2 \tag{1}$$

Where P1 and P2 respectively represent the position of personnel on the platform and the air pressure below the train. For simplicity, it is assumed that these two air pressures are equal.

In order to calculate the air pressure difference, according to the Bernoulli equation, the air pressure difference experienced by the people on the platform can be calculated Δ P (Pascal), as shown below:

$$P_1 + \frac{1}{2}\rho v^2 = P_2 + \frac{1}{2}\rho v_{\text{air}}^2 \tag{2}$$

Calculate the air pressure on a person's body. Next, based on the distance d between the person on the platform and the train, calculate the air pressure F on the person (in Newtons). The expression for force is:

$$F = \Delta P \cdot A \tag{3}$$

Where A represents the area of a person on the platform, which can be estimated based on the volume of the person on the platform. A simplified method is to imagine the person as a rectangle, A=h ·w, where h is the height of the person and w is the width of the person.

Finally, considering a person's weight W, if there is a pressure difference Δ P is the force pushing in the direction of the train ("suction"), and the net force Fnet acting on a person can be expressed as:

$$F_{\text{net}} = F - W \tag{4}$$

If *ΔP* is a force pulled from the direction of the train (" thrust "), then the net force *Fnet* received by the person is:

$$F_{\text{net}} = F + W \tag{5}$$

This model is a simplified one that involves assumptions such as treating people as rectangles. The calculation of specific values needs to be based on specific situations, and calculation software can be used to simulate "suction" or "thrust" under different conditions. This model provides a basic framework that can be further expanded and improved according to actual needs.

The paper MATLAB will be used to calculate the magnitude of the "suction" or "thrust" experienced by people on the platform. The following is an example of a MATLAB script that conforms to the above mathematical model. The script can be saved as a MATLAB script file (. m file) and run in MATLAB:

Firstly, assuming parameters such as train speed, distance between people and the edge of the platform, and weight of people, the Bernoulli equation is used to calculate the air flow rate. Then, the air pressure difference, air pressure of people, and net force are calculated. Finally, output the results to the console. You can run this MATLAB script based on specific problems and parameter values to obtain the size of the "suction" or "thrust" received by people on the platform.

2.3 Research results

Based on the above model and solution process, numerical results of suction or thrust on the platform under different conditions were obtained. Meanwhile, the influence of friction on the platform was analyzed. Through comparative analysis, it was found that:

1) Train speed is the main factor affecting the magnitude of suction or thrust, and the faster the train speed, the greater the suction or thrust.

2) The distance between people and the edge of the platform will also affect the size of the suction or thrust, the farther the distance, the smaller the suction or thrust.

3) The design of the platform (such as height and width) has a relatively small effect on the suction or thrust, but it may also have a certain effect under certain conditions.

Through this diagram, it can be visually seen that the suction or thrust changes with the train speed and the distance between people and the edge of the platform, providing a certain theoretical basis and reference for the setting of safety line markings. At the same time, the limitations and possible improvement directions of the model were also analyzed, providing a basis for further research and optimization, as shown in Fig 1.

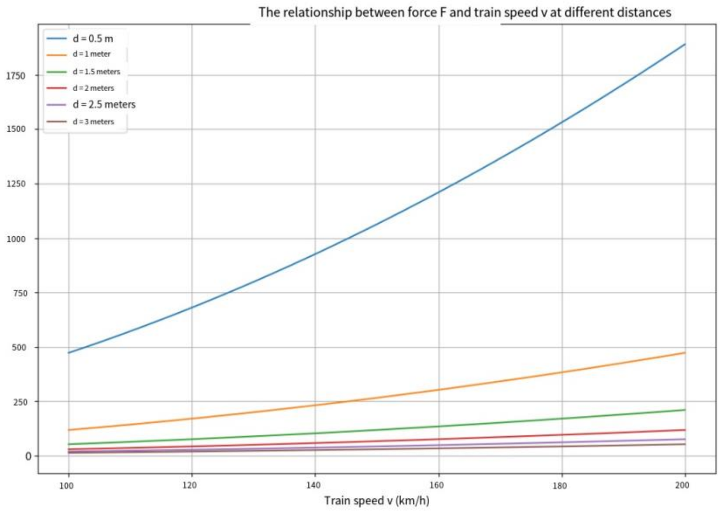


Fig 1: Variation relationship between F and v at different distances

3. The impact of different factors on the setting of safety lines

Explain the basis for setting safety signs on platforms of high-speed trains and bullet trains. Based on the above research results, analyze the impact of different factors on the setting of safety lines, and provide relevant suggestions for railway departments to ensure the safety of railway platforms. After deleting incomplete or inaccurate data, choose a decision model for analysis as it can help systematically evaluate and compare different security label settings.

In order to establish a mathematical model to explain the basis for setting safety line signs at high-speed rail and bullet train stations, it will be based on a mathematical model established based on the Bernoulli effect principle and other relevant factors. Here is a possible model:

The established mathematical model can be used to calculate the "suction" or "thrust" that people on the platform will experience when a train passes through. This force depends on factors such as train speed, distance between people and the edge of the platform, weight of people, platform design, air density, etc.

The setting basis for safety marking can be based on the following principles:

(1) The goal of safety marking is to ensure that passengers on the platform are not in danger when the train passes through.

(2) Safety marking should take into account the forces on the platform. If the "suction" or "thrust" is too large, it may pose a threat to people's safety.

(3) According to the Bernoulli effect principle, the higher the train speed, the greater the force on the platform. Therefore, the setting of safety line signs should consider train speed.

In order to build a mathematical model of the safety marking, consider the following elements:

(1) Train speed: Consider the speed of the train through the platform, the higher the speed, the safety marker may need to be set further away from the platform edge.

(2) Force on a person: Based on the model, the force on a person on the platform can be calculated at different train speeds.

(3) Pedestrian density: The density of people on the platform may affect the setting of safety line markers. In the case of high density, the safety marker may need to be set farther away.

(4) Safety factor: A safety factor is introduced to ensure that human safety can be guaranteed under extreme circumstances.

(5) Platform design and train type: Different platform design and train type may affect the location of safety line marking.

(6) Technical and legal provisions: Consider the relevant technical and legal provisions to determine the location of the safety line marking.

A simplified mathematical model could be:

$$L(v) = k \cdot F(v) \cdot S \tag{6}$$

Where *L(v)* represents the distance from the edge of the platform to the safety marker, *v* represents the speed of the train, *k* is a factor, *F(v)* is the force on the people on the platform, the size of which depends on the speed of the train, and *S* is the safety factor.

The coefficient *k* and the safety factor *S* can be determined according to specific safety standards and regulations to ensure that the people on the platform are not in danger when the train passes.

Friction is considered as a constant factor, and the relationship between train speed, human windward area, and wind force is shown in a three-dimensional diagram. Meanwhile, for the sake of comparison, the horizontal plane of friction force is shown in the Fig, and the safe distance between people and platforms is displayed and marked with the value of the safe distance:

Finally, the model needs to be validated and optimized based on actual data and security standards. This may include considering different types of trains, platform design, passenger density, and other factors. By simulating the train speed and platform design under different conditions, the optimal location of safety signs can be determined to ensure the safety of passengers.

Model validation can be carried out by comparing the predicted safety mark position of the model with the actual safety mark position or industry standards. This process may require collecting and analyzing a large amount of actual data, and may require collaboration with railway safety experts to determine the accuracy and practicality of the model.

This model can be used to guide the setting of safety signs on platforms of high-speed trains and bullet train stations, to ensure that passengers are not in danger when trains pass through. Please note that the specific model parameters and coefficients need to be determined based on the actual situation and safety standards.

3.1 Model solution

Introduce preprocessed data into the above model and obtain evaluation results of different safety sign setting schemes through decision analysis software or programming tools. For programming code, please refer to the attachment. The display of model solutions and results needs to be explained, speak with data, and use charts to display evaluation results and comparisons of different solutions.

According to this model, the net force (suction or thrust) experienced by personnel on the platform at different train speeds can be obtained. This force can be used to evaluate the security of the platform, thereby providing a basis for the setting of safety lines. Please note that specific numerical calculations need to be based on parameters such as actual train speed, platform design, and crowd density to determine the optimal location of safety signs. Use assumed parameter values, including train speed, distance between people and platform edges, and weight of people. Based on the Bernoulli equation, calculate the air flow rate, then calculate the air pressure difference, the air pressure borne by humans, and the net force. Based on the output results, the basis for setting the safety line can be evaluated based on the magnitude of net force and safety standards.

3.2 Result Analysis

Through multiple factor analysis, the degree of influence and interrelationships of each factor on the setting of safety lines were obtained. The results indicate that train speed and platform design are the main factors affecting the setting of safety markings. Based on the analysis results, some suggestions have been provided for the railway department to ensure the safety of railway platforms, such as adjusting the position and width of safety markings, optimizing platform design, etc. At the same time, it also pointed out possible directions that may require further research and optimization to better protect the safety of railway platforms. The research results are shown in Fig 2-6.

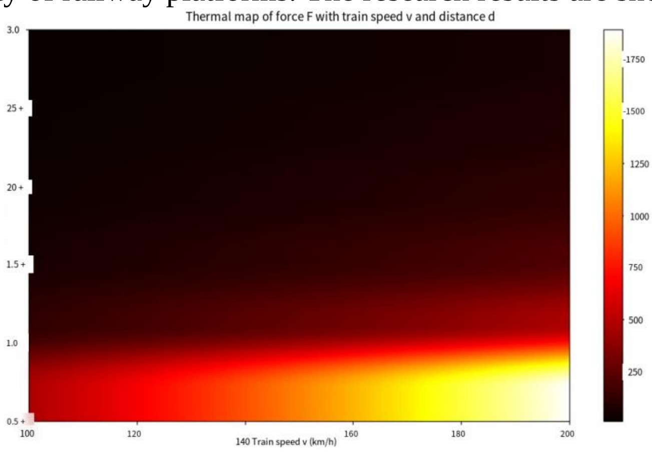
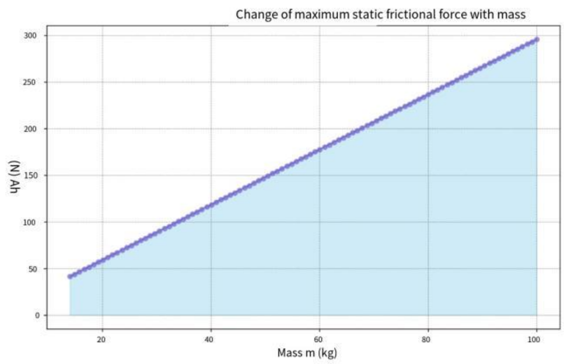


Fig 2: Thermal maps of changes of F with v and d at different distances



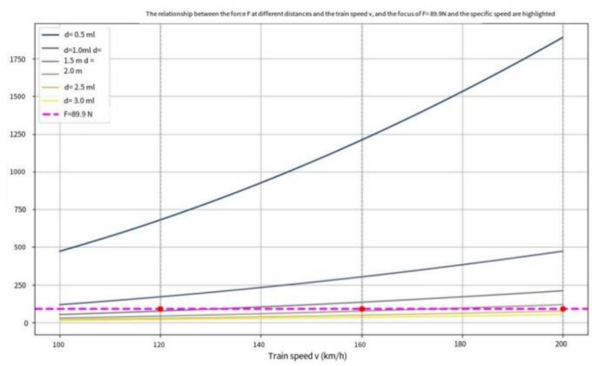
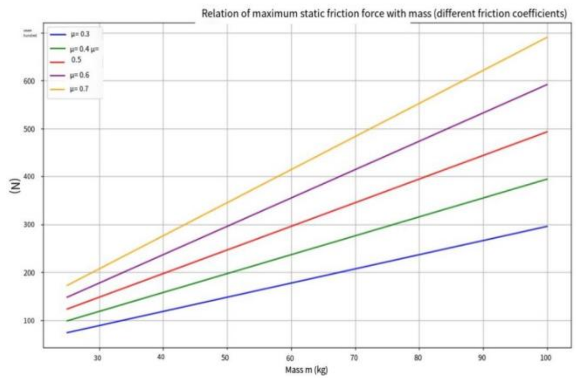


Fig 3: Change of maximum static friction force Fig 4: F vs. v velocity focus



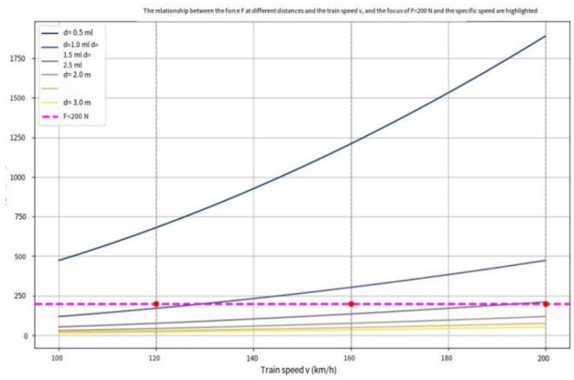


Fig 5: Relation of maximum static friction with mass   Fig 6: F vs. v velocity focus

4. Conclusions

By comparing the calculated results of the model with the actual sampling values, it can be found that there may be some errors. Errors may arise from simplification of model assumptions, estimation of parameters, and complexity of actual situations. For example, the Bernoulli equation used in the model may be too simplistic, without considering the effects of turbulence, air humidity, and temperature changes. This article proposes new perspectives and methods to solve this problem through multi angle and multi-level analysis. Meanwhile, utilizing existing software and tools, the numerical solution of this paper was efficiently and accurately obtained. While ensuring the accuracy of the results, the model has been simplified to reduce computational complexity. Through analysis and comparison, solutions that are in line with the actual situation have been obtained, verifying the rationality of the model. In the future, we can consider applying the model proposed in this article to other similar problems, such as traffic safety, urban planning, and other fields. Through continuous optimization and improvement, the model can have wider applicability and stronger predictive ability.

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